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Persistence and Change of Regional Industrial Activities – The Impact of Diversification in the German Machine Tool Industry

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Abstract.
The paper Investigates stability and change of regional economic activities in the long-run. As the unit of analysis we selected the machine tool industry in West Germany for the years 1953 to 2002. We spot a strong variance in the activities between the different regions. These differences are relatively stable over time and the regional activities are rather path-dependent. Nevertheless, the paper also identifies changes in the level of activities. As the main driving factors for these changes we examine the effect of regional diversification strategies. We find that those regions pursuing a general diversification strategy have a higher likelihood to grow than regions which are specialising. Furthermore, diversification into totally new technological and product fields is only beneficial under specific circumstances based on technological and market developments. Hence, in most cases a broad diversification is superior to one focusing on new state-of-the-art technological fields.

Keywords. Geographic concentration, specialisation indices, machine tool industry, path-dependencies, agglomeration economies.
JEL classification. L61, O1, O18, R11, R12.

1. Introduction

Empirical observations reveal that the regional distribution of economic activities (e.g. measured by firms or employees) is quite uneven in a wide range of industries (Brenner, 2004). While there exist localised industrial clusters with high activity levels in some regions, other regions are nearly deserted. The existence, and in part the emergence of these uneven distributions, can be explained by traditional explanations such as transportation cost arguments. Moreover, Marshall's (1890) ideas on agglomeration externalities offer a second explanatory framework. According to his line of reasoning co-location of specialised firms allows firms in agglomerations to operate more efficiently by sharing some critical resource (Marshall, 1890). In contrast to this approach, positive externalities are argued to be generated by diversity, where knowledge spill-overs occur between organisations with different background (Jacobs, 1969), and are not based on specialisation as in Marshall's approach. There are some studies on localised clusters concluding that a long-term effect of these clusters and a related long-term stability of regional economic activities can be identified (e.g. Brenner and Gildner, 2006). Other studies reveal that although some regional concentrations survive over a very long period of time, others cease to exist (Martin and Sunley, 2006; Grabher, 1993) and potentially new ones emerge – in other regions or in other industries. In order to shed some additional light on these observations we will concentrate on the interaction between stability and renewal of activities in the regions.

One core reason for a decline of economic activities in a region is an exhausted regional technological trajectory. This is accompanied by losing the ability to adjust to a changing environment and to renew the economic activities by integrating new knowledge. In order to sustain a regional competitive advantage the regional interactions and structures must be balanced between stability to generate local synergies and change to introduce new knowledge, products or strategies at the same time (Albino et al., 1999; Bathelt et al., 2004). On the contrary, regions with a low level of economic activities can gain over time when they are more able than stronger regions to adapt to changing environmental and industrial conditions, i.e. when they are more able to cope with the turbulent environmental conditions in the beginning of a new industry or product life cycle.

One important characteristic in the balance between the emergence of synergies based on a certain coherence and stability of regional activities and the renewal of the local knowledge and competence base is the level of specialisation or diversification of regional economic activities (Frenken et al., 2007, Boschma and Iammarino, 2007). In this paper we take the same line of reasoning, but do not only include the level of diversification, but take into account changes in this level. These will in turn be related to different diversification strategies. These diversification strategies are analysed with respect to their effects on changes in the level of regional economic activities.

The existing literature on these issues so far only offers a compromise along the two lines of interest of the paper at hand. While case studies of single regions mostly take into account the development of activities inside the regions and their causes, most studies examining several regions at the same time assume a static context and leave aside possible changes of regional activities. This rather broad approach in the latter type of investigations aims to describe or explain the levels of activities but not the development (for exceptions to this see Fornahl, 2007; Fritsch and Mueller, 2005). In order to get a more profound understanding of the processes, we consider the results of the former studies and add some complementary elements that explain the dynamics of regional economic activities based on changes in some underlying characteristics – in our case the diversification strategies. The focus of analysis is, therefore, not the explanation of variations between economic activities in different regions, but rather we look at an inter-temporally increasing or decreasing level of activity in the regions based on changes in regional characteristics. The time period of analysis covers the post-war period from 1953 until 2002, and thus allows for a detailed investigation of possible changes within industrial and geographical development patterns over a long time.

Hence, the paper aims to answer the questions how stable the activity patterns in the regions are and how different diversification strategies affect the development of these activities.

Instead of analysing the industrial and regional activities in a sectoral context based on sectoral classifications, we concentrate on the product level. The industry under consideration is the West German machine tool sector, which is disaggregated into 39 product classes. Given the high degree of product heterogeneity in the machinery industry especially this fine-grained distinction of lower level submarkets is necessary in order to capture different diversification strategies. Whereas the aggregated level conceals the simultaneous dissolving and emerging of niche markets over time, we are able to monitor these structural dynamics. Therefore, only this differentiation of various product classes beyond the pure technological categorization of metal cutting and metal forming machine types allows for a clearer understanding of the industrial as well as regional developmental paths. The analysis is based on a novel dataset constructed from trade publications between 1953 and 2002. The entire machine tool producer population (2.267 firms) is captured and individually assigned to its region (*Raumordnungsregion*).

We spot a strong variance in the activities between the different regions. These differences are relatively stable over time and the economic activities in the specific regions are rather path-dependent. Nevertheless, the paper also identifies changes in the level of activities. As the main driving factors for these changes we examine the effect of regional diversification strategies. We find that those regions pursuing a general diversification strategy have a higher likelihood to grow than regions which are specialising. Furthermore, diversification into totally new technological and product fields is only beneficial under specific circumstances based on technological and market developments. Hence, in most cases a broad diversification is superior to one focusing on new state-of-the-art technological fields. Additionally, the analysis reveals that after a new technological field is introduced the subsequent evolution of competences necessary to compete in this field also develop and, hence, actors entering the field later do not have disadvantages compared to early movers.

The paper will address the methodology and the results in more detail in the following. The remainder of the paper is organized as follows. Section 2 provides a more detailed theoretical background for the analysis of changes in regional economic activities as well as the impact of diversification strategies. Section 3 gives a general overview on the development of the German machine tool industry and presents the employed dataset. In Section 4 we first analyse the persistence of economic activities in the different regions and second the effect of diversification on the development of regional economic activities. In Section 5 we discuss some core findings of the empirical study, conclude and give an outlook.

2. Theoretical Background

High levels of economic activities or regional growth are often explained by Marshall's (1890) ideas on agglomeration externalities (e.g. Glaeser et al., 1992). These externalities are based on the co-location of firms which enables them to operate more efficiently by sharing some critical resources. Regional social networks as well as labour mobility structure the interaction of agents providing a relatively stable framework for knowledge diffusion and increase the regional knowledge turnover. Hence, knowledge spreads more easily inside a region leading to a specific path-dependency in industrial development (Stuart and Sorenson, 2003). Positive externalities lead to a sustained high level of regional economic activities or even a growth in these activities. But besides these positive externalities, there are also negative ones in densely populated regions hampering the performance of the incumbent firms and potentially even leading to a decrease in regional economic activities. Firstly, there are negative effects based on local competition for scarce resources such as highly qualified human capital or office space. Secondly, high levels of regional activities bear the danger of a negative technological or economic lock-in into an exhausted (previously successful) developmental trajectory. This is especially true when the actors in the region are highly specialized in only one or a few technological or industrial fields. Firms in the regions become too narrowly specialised and internally focused. The regional technological trajectory can for example converge due to very stable and closed networks or by strong exchange of knowledge workers. Hiring managers from organizations that are similar to the focal firm was discovered to have a negative impact on organizational growth (Sørensen, 1999). Such a strong convergence decreases the probability of radical innovations and the entailed high risk of regional lock-in reduces the strategic options of firms. Consequently, the region looses its ability to adjust to a changing environment and to renew the regional knowledge base by integrating new knowledge (Tichy, 2000). With concentration and a too rigid specialization comes a price of fragility.

Studies reveal that although some regional concentrations survive over a very long period of time, others cease to exist (Martin and Sunley, 2006; Grabher, 1993). A turbulent market or technological environment, for example present in the beginning of a new industry or product life cycle, offers on the other side the potential that new regions with high activity levels emerge if those regions are better able to cope with the changing conditions. In general, new knowledge and innovations in the regions – especially radical ones – would lead to a 'wider' development path and an increased ability of the firms to adapt to changing external conditions (Grabher, 1993).

There are in general two alternatives how the regional or industrial structure and the knowledge domains in the region can change over time in order to avoid a negative lock-in in the long-run: first, existing firms can exit while new firms enter the industry and region, hence, the number of firms might stay nearly constant, but the composition of these firms changes over time. Secondly, the incumbent firms can re-orient themselves and offer new products. The new start-ups are of importance for the industrial development in regions because they are one way to introduce new ideas in the regional firm population which cannot be pursued in the incumbent firms. But even these new firms do not guarantee that new products or processes are introduced into the region leading to changes in the existing regional trajectory. Based on the impact of social networks, several studies showed that entrepreneurs will primarily come from and will locate their firms in those regions that already have a significant presence in the field they also want to start their firm in because social relationships facilitate opportunity recognition and the acquisition of intellectual, financial, and human capital (Stuart and Sorenson, 2003). These incumbent organizations provide potential entrepreneurs and human capital later on employed in the new firms (Agarwal et al., 2004; Klepper and Sleeper, 2005). The importance of regional social networks restricts the ability of entrepreneurs to found firms far from their existing locations and in new fields, thereby ensuring that the geographic patterns of entry reinforce the existing distribution of economic activity in any industry and the existing local industrial structure (Sorenson and Audia, 2000; Stuart and Sorenson, 2003; Klepper, 2006). Other studies show that new start-ups cannot only appear in exactly the same industry but in related ones which at least partly changes the industrial structure (Klepper, 2006). Hence, one industry might affect the location or emergence of another industry potentially resulting in a slightly new development trajectory. In the long-run this relationship between industries can lead to a new path-dependency in the regional industrial structure (Brenner and Fornahl, 2008). Thus, new firms can emerge offering old products reinforcing the local path dependency or they can offer incrementally or, less likely, radically new products leading to a change in the local development of the industry.

The re-orientation of incumbent firm towards new products and new knowledge domains can be realized by generating new knowledge by internal R&D processes or external knowledge sourcing as already pointed out above. But these external sources and the generation of new knowledge are more costly and they require more information on potential partners, more reputation to persuade these partners to form a link and higher investment in R&D. Hence, not all firms from a region will be willing to be active in exploration; especially if they are currently successful.

Besides the problem of too few innovations too many innovations in a short period of time or a too strong divergence of economic activities, reduces the likelihood of synergies between the regional activities hampering growth (Nooteboom, 2000). Thus, in order to sustain a regional competitive advantage the regional interactions and structures must be balanced between stability to generate local synergies and change to introduce new knowledge, products or strategies at the same time (Albino et al., 1999; Asheim and Isaksen, 2002; Bathelt et al., 2004). Thus, both a too narrow specialisation as well as a too diverse industrial structure or knowledge domains can hamper future development.

Additionally, the diversity of clusters must refer to their size (Menzel and Fornahl, 2007). Large clusters like the one in Silicon Valley consist of many firms with a great diversity of technologies and knowledge. But also the industrial districts of the Third Italy represent clusters, albeit smaller and in a very specific form. The size and the technological diversity of clusters must correspond to each other: Large clusters can contain a larger diversity than small clusters and nevertheless generate sufficient synergies between firms because of their size. Accordingly, smaller clusters must be strongly focussed to be able to utilise synergies. Hence, clusters with different size will show a different pattern in the different technological fields they are working in.

This reflects the two approaches by Marshall and Jacobs which both focus on knowledge as one of the most crucial resources from which firms generate growth: According to Marshall positive externalities (localization economies) operate in regions which are specialized in one or a few related industries or technologies. In contrast, Jacobs (1969) postulates that knowledge spillovers occur between actors with different experiences, capabilities and knowledge resources and, hence, positive externalities (Jacobs'externalities) are based on regional diversity. There exist several studies which analyzed the effect of intra- and inter-sectoral or -technological spillovers on innovativeness or growth. However, the results of these studies are inconclusive: some studies show that both specialization and diversification positively affect innovativeness or different aspects of innovativeness and its commercialization (Shefer and Frenkel, 1998; Paci and Usai, 1999; van der Panne and van Beers, 2006), while others find that especially diversification externalities favor innovativeness (Feldman and Audretsch, 1999; van Oort, 2002; Glaeser et al, 1992). Other studies found that it is not diversification as such which has a positive effect on growth, but that at least two effects have to be separated: the first one is the positive effect of related variety on knowledge generation and spillovers (Frenken et al., 2007, Boschma and Iammarino, 2008). In this case the different knowledge bases of the organisations in the region or their competences are related or complementary to a certain degree, but are not fully overlapping. Related variety in a regional economy is conducive for interactive learning and enables regions to diversify into new fields and establishing new growth paths while building on their existing knowledge base (Martin and Sunley, 2006). Cognitive proximity between the knowledge held by different regional actors is not too small which would lead to only minor progress and renewal – if at all, but also not too large which would hamper the absorption of knowledge into the individual organisations (Cohen and Levinthal, 1990). Such an optimal distance between the regional knowledge bases is particularly advantageous for interactive learning and regional growth. The second one is based on unrelated variety representing a portfolio effect which protects the region against sector-specific external shocks. In this paper we take a slightly different perspective and do not only include the level of diversification, but take into account changes in this level which we relate to different diversification strategies resulting in an extension or reduction of competences. We focus our analysis on three different aspects of such diversification strategies: 1) a general diversification strategy analysing whether the number of different activities in the regions changes (in our empirical example based on changes in the number of product categories the firms in a region are active in as well as in the distribution of activities inside the product categories). This strongly follows the portfolio argument mentioned above.[1] 2) A specific diversification strategy in 'state-of-the-art' product fields which are close to the technological frontier. 3) Additionally, we take into consideration at which points in time the specific diversification strategy is introduced in the regions in order to examine whether regions following this diversification strategy early in the product life cycle have advantages over regions following later. This would indicate that new competences acquired early in the product life cycle generate a longer-term competitive advantage.

[1] We also examined the effect of related variety but for different reasons mentioned later in the paper, we are not able to follow this line of research.

In the end we analyze how these different diversification strategies affect regional economic development measured by changes in the level of activities. This is based on the assumption that two aspects must be balanced in order to profit from local synergies and the advantages of local interactions but at the same time to access new knowledge: first, the exploitation of existing development trajectories moderated by stable networks and internal convergence and second, the exploration of new trajectories by own learning processes and the integration of new external knowledge. If such a sustainable state is achieved we can observe a relatively high and stable number of firms, employees, innovations, etc. on the regional or industrial level, while at the same time on the firm level, the products the firms offer, the processes they employ and the interactions they have with other organisation change over time. One important characteristic affecting this balance is the level of specialisation or diversification of regional economic activities as well as changes therein.

Thus, the paper aims at answering the questions whether the activity patterns in the regions are stable or changing over time and how different diversification strategies are more or less beneficial for economic development measured by the level of economic activities.

3. Data and Historical Background

3.1. Data

The upcoming analysis is based on the following data sources: The buyer´s guide “Wer baut Maschinen” (“Who makes machinery”), issued annually by the Verein Deutscher Maschinen-und Anlagenbau (VDMA) since 1932, was used to construct the employed dataset. It encompasses the entire firm population of machine tool producers for the time period 1949-2002.[2] We only use the information for West German firms (including West Berlin), as the Eastern part of the population was not listed throughout the times of the inner German separation from 1962-1989. We gathered data concerning the location of each firm on the level of 74 *Raumordnungsregionen* (regional planning districts), and categorized their products along 39 product classes.[3] Moreover, census data are used to calculate regional population density as a proxy for urbanization economies. The full time period from 1953 until 2002 is divided into five periods each consisting of ten years; thus we obtain: P1 (1953-1962); P2 (1963-1972); P3 (1973-1982); P4 (1983-1992); P5 (1993-2002).

3.2. Historical development of the German machine tool industry

The origins of modern machine tool building can be traced back until the end of the 18th century and are closely connected to the invention of the steam engine and its advancement by James Watt (Weck and Brecher 2005). While the history of machine tool

[2] For the years 1949 and 1950 only one catalogue was issued; therefore the values for those two years are identical. The catalogue for 1952 is not accessible; therefore the values for 1952 are approximated by the respective values in 1951. Because of these missing data our analysis starts in 1953.

[3] This classification goes beyond the mere differentiation of metal forming and metal cutting products. Products are hierarchically categorized into six technology groups on the first level, and another 39 product classes on the second level based on the VDMA scheme in the buyer´s guide.

building then started as a predominately British story, the United States grew into the world leadership position by the end of the century. German manufacturers only entered the scene as a serious international competitor at the turn to the 20th century, but their high quality standards enabled them to challenge U.S. supremacy.

Soon the German machine tool industry relapsed heavily due to both World Wars, the entailed destruction of production facilities and engineering drawings (Schwab, 1996), and the subsequent dismantling of plants as part of the post-WW2 restitution schemes (Mazzoleni 1997). But the reconstruction of Europe's manufacturing industries was on the contrary also the driving factor for the sector's recovery in the 1950s and 1960s (Arnold, 2003). Output and exports of German producers profited from this trend and continued to grow well into the 1990s. In the beginning of the1990s a severe crisis in terms of production, exports, and employment could be witnessed (VDW, 2005) which was caused by structural (Guenther, 2008) as well as external factors[4]. But the increased service and customer orientation on the international market and reorganization of production processes as well as increased efficiency helped the German machine tool sector out of the crisis in the second half of the 1990s (Deutsche Industriebank, 2004).

Throughout the course of time in the second half of the 20th century demand conditions changed all over the place. In particular, there was a clear trend towards a buyer's market with increasingly sophisticated customers asking for machines with stricter tolerance, higher precision and a high degree of automation (WS Atkins Management Consultants, 1990). Among them the automobile industry as one of the major customers continuously enlarged its product portfolio and demanded increasingly flexible and versatile machine tools to produce a variety of models (Fleischer, 1997; Roy and McEvily, 2004). Additionally, "ordinary" end-users demanded increasingly flexible and adjustable machinery as their own development cycles shortened and the pressure to minimize time to market, massive cost reduction, and increasing flexibility of production processes came to the fore (Hirsch-Kreinsen, 2000). This request for advanced flexible manufacturing became an overarching issue in the general international customer base and thus called for innovations dealing with these changing requirements. The development of numerical controls (NC)[5] and their computerized successors (CNC) served exactly the aforementioned purpose and allowed, amongst others, for the construction of multi-functional machinery and products (MFP) such as machining centers and flexible manufacturing cells or even entire flexible manufacturing systems[6]. These machining concepts integrate several single function-specific machines, e.g. drilling, milling, and

[4] These factors include for example the collapse of the Soviet Union (Schwab, 1995) as one of the major customers, the inability to act as a global player because of the small and medium sized company structure within the industry, and the adherence to "over-engineered" machines (Hirsch-Kreinsen, 2000; Carlsson, 1989).

[5] (Computerized) numerical controls operate the tools automatically with the help of computerized control tapes which contain pre-programmed sets of commands. All process relevant actions, such as machine feed and speed, selection of a particular tool, distance and direction are carried out automatically as opposed to a skilled worker continuously supervising the production processes. By changing the set of commands and thus the processing instructions an entirely different operation can be initiated (Arnold, 1997).

[6] A flexible manufacturing system (FMS) is defined as " a grouping of CNC machines (often including machining centers) which is fed by an automatic materials handling and transfer system meeting the needs to manufacture small and medium batches of a variety of products" (WS Atkins Management Consultants, 1990, p. 53). Flexible manufacturing cells (FMC) and machining centers are also based on CNC technology, but contain fewer machines/tools than FMS.

boring, thus rendering conventional stand-alone one function machines almost obsolete, technically speaking (Arnold, 2003). The main advantage of these integrated CNC-based multi-function machine tools is the automation of various subsequent processing steps. Thereby, a reduction in labour input can be realized as no direct human intervention is necessary to guide the process as in the case of former conventional machinery, e.g. to transfer the work-piece from one job to the next one, but instead interchangeable pre-programmed sets of commands are employed. This does not only save time when retooling the production line, but it also increases its flexibility and guarantees a constant quality by ensuring high accuracy when repeating a defined machining process (Carlsson, 1984). This in turn allows for fast responses to customer needs, model changes, and product improvements (WS Atkins Management Consultants, 1990).

But the development of NC/CNC products has to be seen as a dynamic process in itself. Basic numerical controls were already introduced in the 1950s and 60s. But whereas these early numerical controls were simply connected upstream the existing machining concept, later versions induced a change in the entire product architecture. Only this advancement, i.e. the successful integration of computers in the 1970s and 1980s, brought about the attractiveness and commercial breakthrough of highly flexible machinery based on (computerized) numerical controls on a broad level, because it allowed for the unfolding of the full potential in terms of flexibility, time-saving, increased quality, and reduction in waste and rejects (Carlsson, 1984) and eased the programming part (Arnold, 1997).[7] With this development the required competencies shifted away from the purely mechanical accuracy towards micro-electronic capabilities (Arnold, 1997). Therefore, besides all the advantages of CNC-based multi-functional products, the main challenge in offering these machines lays in the combination of various specialized competencies, disciplines and actors into the conceptualization of the machine. This is not only limited to the integration of microelectronics into existing machinery. In order to exploit the full potential of the new technology the entire product architecture changed and new competencies had to be developed (Arnold, 1997).

Based on the prosperous post-war period and the strong international position in niche markets, German manufacturers did not stimulate the diffusion of numerical controls and the accompanied highly flexible machining concepts on the domestic market for a long time. Instead, they mainly relied on conventional machining concepts and concentrated on high quality customized products. Nevertheless, they were involved in state-of-the art-technology, i.e. the development of CNC machines and were able to adapt their markets in the light of changing demand conditions and increasing international competitive pressure especially by Japanese manufacturers.[8] One channel of this adaptation and re-orientation was to utilize the growth potential inherent in the described emerging demand for flexible manufacturing solutions in form of multi-functional products.[9]

[7] This development was accompanied by significant price drops, which made the technology feasible also for smaller job-jobs (Schwab, 1995). Moreover, the given economic situation of rebuilding the European industrial equipment after WW2 held back the immediate shift towards numerically controlled machinery (Guenther, 2008).

[8] For a detailed description of the adaptation process and how numerical controls were chosen in favor of alternative concepts see Guenther (2008).

[9] Even though, the new control technique was also integrated into single-function machinery, we concentrate our analysis on multi-functional machinery as the implementation of the changing market requirements is most remarkable and complete in these machining concepts.

From a regional perspective the question arises, which regions managed to master the innovative challenge towards multi-functional products, and whether they develop more prosperous than the industry in general.
Empirical investigations dealing with a regional perspective concerning the German machine tool industry are mostly restricted to identifying the most active Federal States, namely Baden-Württemberg, North Rhine-Westphalia, Hesse, and Bavaria, which dominated throughout the post-war era (VDW, 2005; Schwab, 1995[10]). Besides the fact, that the level of Federal States is rather broadly aggregated, all remaining regions are not dealt with in particular. Therefore, we extend the analysis with respect to two dimensions; firstly we investigate *all* regions within the West German machine tool industry. Secondly, we choose the detailed level of *Raumordnungsregionen* as opposed to the Federal States as the unit of analysis. By these means we are able to uncover the dynamics within the Federal States over time. Moreover, we can identify whether the relative positioning of the regions remained constant and whether the situation is indeed as stable as claimed.[11]

4. Analysis of Persistence in Regional Economic Activities

4.1 Stability in Size Ranking and Instability in Growth

Based on the theoretical considerations in section 2, the following sections explore the stated hypothesis that the general diversification processes in a region as well as the entry into the latest product fields (in our case MFP) facilitates regional growth processes. We start this analysis by investigating the stability of machine tool activities within each region and their resulting changes in rank positions (RC) based on the number of firms in a region. Subsequently, we present the development of growth patterns based on the concept of relative competitive advantages (RCA) before we explain these observations.

Early studies identified Baden-Württemberg, North Rhine-Westphalia, Hesse and Bavaria as the most active Federal States during the post-war era. We extend this analysis by investigating the ranking of all regions on the level of Raumordungsregionen and its persistency before we take a closer look at the top regions. Thus, for each of the five time periods we determined the ranking of all regions based on the number of machine tool producers within the individual regions.[12] As a first step, we analyzed the stability of the overall machine tool activities in the regions. For this, we examined whether the rank positions of the regions are stable over the five time periods or whether we observe strong

[10] Schwab (1995) explicitly mentions Stuttgart and the Rhine-Main area as two highly active regions.
[11] Fleischer (1997) chose a similar approach by investigating whether the rank positioning of the top firms remains constant over time. His analysis is though limited to the time period 1990-1994, but he nevertheless founds a high mobility of firms during these years.
[12] In addition to the analysis based on the absolute number of firms, we also calculated all rank correlations based on the number of firms weighted by the population density within the region. The results remain the same and, hence, only the results for the absolute number of firms are presented in the following.

variations. Table 1 shows the Spearman rank correlation coefficients between the defined time periods.

Time periods	Time periods 1	2	3	4	5
1	1	0.9738	0.956	0.9166	0.8772
2		1	0.9752	0.9375	0.8978
3			1	0.9702	0.9264
4				1	0.9479
5					1

*Note: all correlation coefficients are significant on the 1%-level

Table 1: Rank correlations between 5 periods of time (basis: absolute number of firms in region)

The main conclusion to be drawn here is that we observe a strong correlation between all periods, ranging from a correlation coefficient of 0.8772 (period 1 and period 5) and 0.9752 in the case of period 2 and period 3. In particular this means that the ranking in one period highly depends on the previous ranking throughout the entire time interval. This in turn leads to the conclusion that the ranking among the regions is very stable over time, even over a period of 50 years with a correlation between every time period t and the subsequent period t+1 is very strong (correlation coefficient: 0.9876).[13]

The just described strong stability in rank positions is also visible in the top ten regions with respect to their maximum number of firms. Table 2 depicts these ten regions with the highest number of firms in 1953 and 2002. Whereas Düsseldorf and Stuttgart are always by far the largest regions and seven of the ten top regions in 1953 are still in the list in 2002, we also observe some regions that exit or enter the top ten (in italics). In particular, while Berlin, Hamburg, the Industrial Region Middle Franconia leave the list, Siegen, Neckar-Alb, Southern Upper Rhine and Upper Franconia West join the top ranks. A closer look at the precise number of firms within these regions reveals however that the economic activities in the regions underwent drastic changes throughout the course of time, although the ranking appears to be stable at first glance.

[13] We did the same rank correlation analysis for each individual year and observed a minimum value of 0.77 (comparing the rankings of 1954 and 2002) for the correlation coefficient, which is significant on the 1%-level.

Rank	Name of region	Number of firms in 1953	Name of region	Number of firms in 2002
1	Düsseldorf	169	Stuttgart	42
2	Stuttgart	70	Düsseldorf	40
3	Bochum/Hagen	50	*Siegen*	22
4	*Berlin*	39	Northern Black Forest	18
5	Northern Black Forest	39	Bochum/Hagen	17
6	Rhine-Main	37	Black Forest Baar-Heuberg	15
7	Cologne	24	Rhine-Main	12
8	*Hamburg*	17	Cologne	12
9	*Industrial Region Middle Franconia*	17	*Neckar-Alb*	9
10	Black Forest Baar-Heuberg	16	*Southern Upper Rhine*	9
11			*Upper Franconia West*	9

Table 2: Regions with highest number of active firms

Starting with 169 firms in 1953 the number of firms in Düsseldorf was quartered until 2002. The decrease was less radical for Stuttgart, Bochum/Hagen, Northern Black Forest, Rhine-Main and Cologne, but nonetheless sizeable between 40% (Stuttgart) and 67% (Rhine-Main). Considering the new members among the top ten regions, it becomes clear that their relative success is mainly caused by a rather stable number of firms and not because of actual growth, except for Siegen, which grew clearly by 7 firms from 1953 until 2002. Southern Upper Rhine and Upper Franconia West each increased their firm population by only one respectively two firms, and Neckar-Alb ended with four firms less than it started. Hence, the new entries in the top list on average have not grown considerably, but the better position in the ranking was caused by relative stability in the number of firms. Caused by this stability the regions developed better than the industrial trend, which showed a reduction in the number of firms.

But it was not only in the top ten regions where we can observe stability as well as change patterns. The dynamics with respect to regions changing their rank position are given in Table 3. The share of regions changing the rank by less than three, five, ten, fifteen or twenty positions are indicated for all possible transitions between the 5 periods. The main conclusion to be drawn from this table is the confirmation of the quite stable ranking of the regions. Looking at the share of regions that underwent less than 10 rank position changes from period 1 to period 2 already 97 % of all regions are covered. This picture does not change considerably when investigating the other t to t+1 changes as well as the changes over longer periods of time; even between the first and the fifth period 74% of the regions only changed their rank by less or equal eleven positions. The last column of Table 3 depicts the regions with the highest increase or decrease in rank positions. In this case the higher the number of firms in a region the higher the rank position. Whereas the regions Saar and Bavarian Lower Main are identified as the top achievers, Bremen, Schleswig- Holstein South, Brunswick, and Hannover are the regions with the severest downswing in the number of firms.

Change from one period to another		Number of ranks changed 0	<=3	<=5	<=10	<=15	<=20	>20	MAX
1➔2	(Cum.) Share	0.19	0.60	0.74	0.97	0.99	1.00	0.00	(15➔35;Saar)
2➔3	(Cum.) Share	0.18	0.58	0.84	0.95	1.00	1.00	0.00	(33➔18; Bremen)
3➔4	(Cum.) Share	0.15	0.58	0.73	0.92	0.99	1.00	0.00	(18➔1; Bremen)
4➔5	(Cum.) Share	0.16	0.48	0.68	0.89	0.97	0.97	0.03	(52➔22; Schleswig-Holstein South)
1➔5	(Cum.) Share	0.11	0.36	0.42	0.74	0.82	0.92	0.08	(33➔7; Bremen) (58➔32; Brunswick) (31➔57; Bavarian Lower Main)

Table 3: Rank changes between time periods (basis: absolute number of firms in region)

Table 4 represents six indicators describing the development of the number of firms on the regional level based on the ten-year intervals. As can be seen in the table there is a rather stable average number of firms in a region; the same stability can be observed for the median, 25% and 75 % percentile during the first 4 intervals. Comparing the fourth and the fifth interval we see these values declining. Investigating the maximum number of firms the decline becomes visible already after the first period. But this decrease is entirely driven by the development of Düsseldorf. While the total number of firms stays constant during the first two periods it decreases strongly after the second period, and even more so after the fourth period.

	1953-62	1963-72	1973-82	1983-92	1993-2002
Min	0	0	0	0	0
Max	150.6	129.5	99.2	83.2	60.2
25%	1.7	2	2	1.4	1
Median	5.1	5.2	5.2	4.6	3.1
75%	9.4	10.9	9.7	9.2	8
Total number of firms	756.7	756.8	662.7	606.6	460.9
Mean number of firms in a region	12	12	10.5	9.6	7.3

Table 4: Average number of firms in ten year periods (basis: absolute number of firms in region)

Figure 1 shows the development for the maximum number of firms, the 95% and 90% percentiles of the distribution (measured on the primary axis) as well as the 75%, and 50% percentiles (measured on the secondary axis) between 1953 and 2002 for all regions. The maximum number of firms in one region decreases drastically over the course of time from 162 in 1955/56 to 42 in 2002. This figure is entirely driven by the developments in Düsseldorf and Stuttgart.

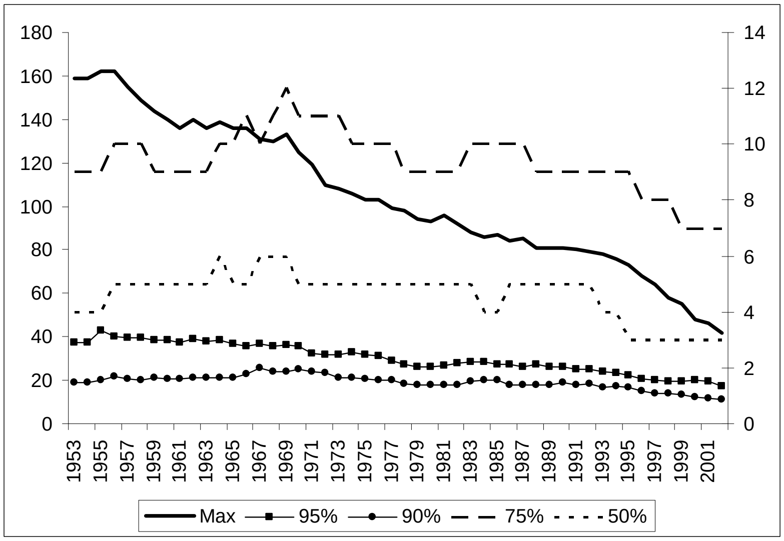

Figure 1: Development of number of firms 1953-2002

The 95% percentile confirms this steady downward trend. But looking at the 75% percentiles we see, that these “upper midsize” regions even grew from the 1950s until the 1970s before they slowly shrink in the remaining years. The median nearly remains constant between the end of the 1950s and the beginning of the 1990s.
Thus, we can conclude that the experienced growth in the number of firms between the 1950s and 1970s was realized by the “upper midsize” regions, and not by the large regions. Furthermore, we identified a relatively high stability with regard to the rank positions of the regions, but at the same time we also found that at least some rank changes take place and that a very small set of regions even experience very strong variations in rank positions over time.

We now turn to the analysis of these regional growth and decline patterns by investigating the relative competitive advantage (RCA) of regions over time. The RCA is defined as

$$RCA_{t-t+1} = \tanh \ln((p_{t+1} / p_t)/(P_{t+1} / P_t))$$

with p = number of machine tool firms in a region and P = number of machine tool firms in Germany whereas t denotes single years or aggregated time periods. The RCA measures the relative development in the region compared to the industrial trend. A ‘0’ indicates a matching between the regional and the industry development, while for negative values the region develops worse than the industry trend and vice versa for positive values. Figure 2 displays the development of the RCA over time.

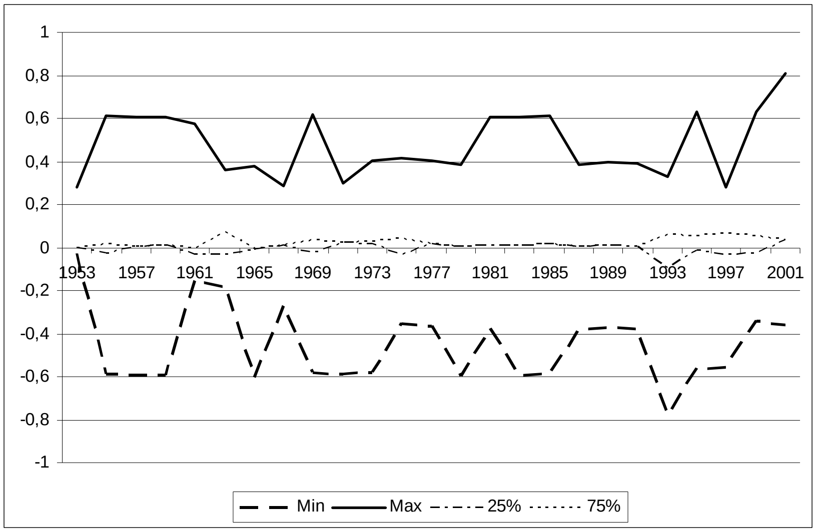

Figure 2: Development of RCA between different years over time

As can be observed in Figure 2 the minimum and maximum of the RCA stay relatively constant over time being limited by 0.6 and -0.6 respectively. Furthermore, the development is symmetric to a certain degree: an increase in the maximum often is linked to a decrease in the minimum. Hence, there are certain years with a high turbulence in which some regions develop strongly positively while others develop negatively. Only in the last years of observation the maximum is increasing while the minimum is increasing as well.

Table 5 represents the rank correlation for the various growth intervals. The growth intervals are defined as the RCA between two ten year periods. The only correlations which are significant but have very low coefficients can be observed between the first and the second, and the second and the fourth period.

Growth intervals	**Growth intervals** P1-P2	P2-P3	P3-P4	P4.P5
P1-P2	1			
P2-P3	-0.2162*	1		
P3-P4	0,1726	-0,0206	1	
P4-P5	-0,0837	0.2468*	-0,1742	1

*Note: correlation coefficient is significant on the 10%-level; all others are not significant

Table 5: Rank correlations between 4 growth intervals (basis: RCA)

This is in contrast to the results obtained for the rank positions measured by the absolute number of firms, where we found that the ranking in one period is highly correlated with the position in a later period, even over a 50 years time horizon. For the growth indicator we can conclude that a region which grows in one period can either continue to grow, shrink or not change at all. Moreover, the analysis of rank changes with respect to this growth indicator also reveals, that the situation is less stable than it first appeared to be. Whereas we only observe moderate rank changes based on the number of firms in a particular region, we found, that a ranking based on the RCA describes a quite dynamic situation. We generally observe more rank changes, a higher magnitude, and varying regions in the top ten.

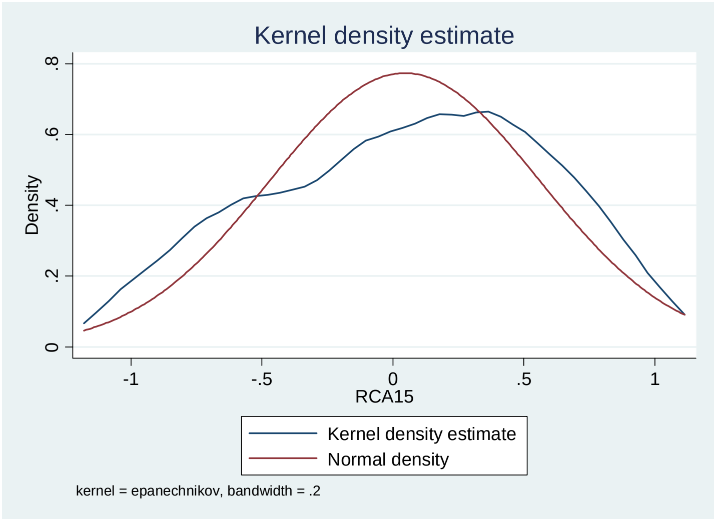

Figure 3: RCA between Period 1 and 5

Figure A.1 in the Appendix depicts the Kernel density estimates for the RCA between two succeeding periods as compared to the normal distribution. Except for the transition from period 3 to period 4 all figures show a deviation form the normal distribution. Figure 3 shows the Kernel density estimates for the RCA between period 1 and period 5: the observed curve is below the normal distribution around zero, but above the normal distribution at both ends. Thus, we have way more regions that shrink than we expected in the one hand, but also more regions that grow than expected. Looking at these patterns for the individual time periods (Figure A.1 in the Appendix), we observe that from period 1 to period 2 there are more regions that grow in this phase than estimated. This means that in the phase of rebuilding the German manufacturing sector, more regions than expected were able to use this growth potential to their advantage. For the periods 2 to 3 as well as period 4 to period 5 more regions than expected shrink. Thus, there are more regions than predicted that suffer from the initiation of the general downward trend in the case of the development from period 2 to period 3, and the crisis in the beginning of the 1990s (P4 to P5). In the remaining interval, period 3 to period 4, we observe extraordinary many regions which either grow or shrink than predicted.

4.2 Explaining Changes in Rank Positions and Growth Patterns

After having analyzed the relative stability in size ranking and the instability in growth patterns, we turn now to the examination of reasons for changes in rank position as well as growth activities. The foci of our investigation – our dependent variables – are rank changes between specific periods in time (based on the number of firms) as well as growth patterns measured by the RCA.[14] We take into account short-term developments by analyzing subsequent periods in time as well as long-term developments spanning several time periods (1-4, 2-5 and 1-5). We include five categories of explanatory variables in the analysis. First, the number of firms in the start period as an indicator related to agglomeration externalities and advantages or disadvantages of being located in a localized industrial cluster. Second, we include the general degree of specialization (measured by the Hirshman Herfindahl Index HHI based on the number of products in the different product categories) and the change in this HHI between the start and the end period. The HHI represents the general level of specialization in the region with low values indicating a relative equal distribution of activities over the product categories. Third, changes in the number of product categories in which products are generated in the region. An increasing number of product categories stand for a general diversification strategy. Fourth, we take into account whether or not the firms in a region are offering multi-functional products (MFP). This is a peculiar diversification strategy into state-of-the-art products. Fifth, we examine the timing of entry into MFP affects the dependent variables. All variables are correlated with a correlation coefficient below 0.5, thus there is no indication for multicollinearity. The summary statistics are presented in Table A.1 in the Appendix. We apply robust OLS-linear regressions (Tables A.2 and A.3 in the Appendix) and add results from an ANOVA study where applicable[15].

The first conclusion to be drawn is that regions with a high number of firms in the start period develop worse than the industry in general. A negative effect on rank changes can be detected for those analyses including the last period of observation as the ending period. This indicates that there seems to be no advantage of being located in an industrial agglomeration. On the contrary the effect is even negative in most cases.

Secondly, the general degree of specialization (HHI) in the start period does neither affect the RCA nor the rank position of the region. But if the activities in a region specialize in certain fields over time being measured by the *change in HHI*, a negative effect on the development of regional activities compared to the industrial trend can be recorded for the last periods of observation. The long-term developments are not influenced by changes in the HHI.

Thirdly, considering the number of product categories as well, it becomes clear that the more product categories a region enters between the defined start and ending period (and thus follows a general diversification strategy), the better the regional development concerning rank changes as well as the RCA. An ANOVA analysis supports this finding and shows that rank changes between the first and the fifth period are significantly affected by a change in the number of product categories a region is active in. In particular, regions entering additional product categories increase their rank position whereas leaving a product category leads to a decrease in the regions relative ranking.

[14] For a similar approach based on start-up data see Fritsch and Müller (2005).

[15] We also applied Tobit and Truncated regressions (with -1 and 1 as lower and upper limit for the regressions with RCA as dependent variable as well as 0 and 64 for the regressions with Rank Change as dependent variable) and Generalized Least Square regressions. We receive identical signs for all coefficients and some slight deviations with regard to the significance of the variables, but these results do not contradict the findings of the robust OLS regressions. We only report the results of the robust OLS regressions in the following.

Taking the results together, we find that diversification has a positive effect on the development of regional activities or regional growth.[16]

Despite this general positive effect of diversification on regional growth, we are especially interested in the effects of entry into the described multi-functional product categories (MFP). Before we analyze this specific effect, we investigate which regions do enter these product categories at all. First of all, entering regions have the highest number of firms at every point in time. This means, that large regions with a high rank position enter the product categories of MFPs, and are still the most densely populated regions considering the number of firms at the end of the analyzed timeframe. Secondly, regions getting engaged into producing MFPs have always been comparably strongly diversified. This might generally be due to several reasons: first, regions with more firms have the possibility to offer a larger product portfolio to spread the risk simply because there are more producers. Second, firms within these regions have the necessity to "stand out in the crowd", and are therefore more inclined to opt for additional (niche) submarkets. Small regions in contrast tend to specialize based on the limited number of firms alone, or even intentionally choose to specialize in order exploit potential synergies to enhance their competitiveness. Besides these general causes for large regions to be more diversified there is a third reason for the specific case at hand. As explained in section 3.2. multi-functional products integrate various traditional metal working processes. The presence of a broad knowledge base provided by numerous specialists within a region might thus enhance the realization of these new machining concepts.[17] In smaller regions, some of these individual competencies might simply be missing and therefore render their integration impossible. Over time these observed specialization respectively diversification tendencies lead to a co-existence of increasingly diversified regions on the one hand, and regions which are specialized or concentrate on niche markets on the other hand.

Investigating the development of these different types of regions, the ANOVA analysis reveals that large, diversifying regions lose more firms than their smaller and specialized counterparts when being measured in absolute numbers. This might be simply due to the fact, that these regions are larger and have therefore more firms to be closed down. But the inspection of the RCA, and thus a relative measure to the industry trend, shows that regions becoming active in MFPs developed better than the overall industry from the first to the last period. Their relative advantage becomes even more visible between the fourth and the fifth period, when they clearly outperform non-entering regions. In the multivariate regression we disentangle the effect of entry in MFPs from the general effect of the size of the region (controlled for by the number of firms in the start period). The effect of entry into these new product fields is very high compared to the other coefficients with entry having a positive effect on rank changes of more than 7 positions. The results indicate that both changes in rank position as well as growth processes compared to the industry trend are only positively affected by entry in MFPs between the

[16] Despite some problems in calculating related and unrelated variety, we tested them as well, but related variety is never significant and unrelated variety delivers the same results as change in product categories and change in HHI. We omitted the results here because of the problems in calculating these variables (many zeros as nominator or de-nominator)

[17] Even though, numerical controls required a change within the entire product architecture, specialized knowledge in individual processing procedures was nonetheless still valuable.

fourth and fifth time period. Hence, this peculiar diversification strategy into new product or technological fields has not a positive effect throughout all time periods but only at a very specific point in time when the market success for these types of products is achieved. As explained in section 3.2. the commercial breakthrough came only with the ending of the prosperous post-war period and the shift from numerical controls to their computerized successors in the 1970s and 1980s when the full potential of the new technology could be exploited. Thus, very early experience in this new technology field[18] was not beneficial on the regional as the implementation of the truly profitable features and advantages required a change in the entire product architecture and the development of new competencies, especially in the field of micro-electronics (Arnold, 1997).

As a last aspect we investigated whether regions entering into MFPs at different points vary in certain respects, and whether the timing of entry into MFPs affects the subsequent development significantly. We therefore differentiate between early movers (entry into MFP in period two), early followers (entry into MFP in period three), and late movers (entry into MFP in period four or five)[19]. Supporting the results in the previous section, we found by an ANOVA that those regions with the highest number of firms in the very beginning turn into early movers. Moreover, we observe that these early movers still have a significantly larger number of firms and thus a higher rank position in the last period than early followers, even though they lose more firms in absolute terms. Looking at their development in absolute and relative terms, early movers even shrink more drastically than regions that do not enter at all. Late movers in contrast do not show any significant difference in size neither with respect to early movers nor in comparison with non-entering regions. But late movers clearly differ in their development when being compared to non-entering regions. Regions which enter MFP in the fourth or fifth period significantly outperform their non-entering counterparts in the very same periods. Non-entering regions develop even worse than the industry trend measured by the RCA. Interestingly, we found evidence against a first mover's advantage. Whereas late movers outperform non-entering regions in the fourth and fifth period (thus after their entry), early movers develop worse than regions entering later than the second period and as non-entering regions. The same results emerge from the multivariate analysis: although in most cases entry into MFPs in general has a positive effect, this does not hold for entry in period 2 for RC45 and RC25. Hence, early entrance has no effect on rank changes in the critical market phase between the fourth and fifth period. Additionally, we found for growth processes compared to the industry trend that the coefficients for entries in period 2 are never the highest compared to entries in later periods (for RCA45 entry in period 3 and for RCA25 entry in period 4 have the highest coefficients). This might generally indicate that those regions entering later can imitate or reduce the risk of employing unsuitable processes and products. Early experience and knowledge seem to be less valuable. In the specific case of the German machine tool industry, this development can also be explained in the following way: While German producers as well as their customers relied on conventional machine tools for a comparably long time the necessity

[18] Early experience relates to know-how with the precursors of CNC machines, in particular basic numerical controls, which did not necessarily include changes in the mechanical engineering part of the machine.

[19] Entry into MFPs before the second period was not possible, because these categories simply did not exist before the 1960s.

to enter these new technology fields was less pressuring than on international grounds. Moreover, in the light of a prosperous reconstruction post-war period and a dominant international position, German producers could so far survive based on their traditional products. During these days conventional and single-function products were also still capable of competing via the comparably low price and were thus attractive especially for smaller job shops. But with the integration of reasonably power-full computers into numerical controls in the 1970s the full potential of this technology could be used and was also increasingly demanded partly due to sharp price drops. Thus, the necessity as well as the potential gain from entering into MFPs tremendously increased with the technology's commercial breakthrough in the light of a changing economic situation rather lately.

5. Summary and Outlook

According to the literature a certain level of stability of regional interactions and structure is required in order to generate local synergies. But at the same time a sufficient degree of change, i.e. the introduction of new knowledge, products or strategies, is necessary to sustain a regional competitive advantage (Albino et al., 1999; Asheim and Isaksen, 2002; Bathelt et al., 2004). One major influence factor of this balance between emerging synergies based on a stable level of regional activities and the renewal of local competencies and knowledge is the level of specialization respectively diversification of regional economic activities (Frenken et al., 2007, Boschma and Iammarino, 2007). This degree of diversification in turn clearly depends on the size of the region (Menzel and Fornahl, 2007). The paper at hand contributes to this debate on regional activity patterns by analyzing how different diversification strategies influence changes in the level of regional activities. In addition to these general effects of diversification we investigated in particular which regions enter into a newly emerging technology and in how far this influences the subsequent development of these regions. Furthermore, differences in timing of entry into "state-of-the-art" product fields were analyzed. The analysis was conducted for the case of the West German machine tool industry between 1953 and 2002. Within this time period the development of numerical controls and especially their computerized successors marked the beginning of a new technological trajectory by opening up the potential to diversify into newly established multi-functional products.

The main findings of the empirical investigation can be summarized as follows. First of all, we observe a rather stable situation with respect to the ranking of regions based on the absolute number of firms in a region. Hence, the relative positioning of the regions does not change considerably even over a period of 50 years. But this high level of stability is put into perspective when looking at the development of the number of firms respectively their growth patterns. Measuring the relative competitive advantage of the regions, i.e. a relative measure of the regions development compared to the industry trend, we observe several waves of high turbulence. Moreover, there is no correlation to be observed between growth in one period and a succeeding one. Thus, depending on the basis of establishing rank correlations, i.e. either based on the absolute number of firms or by the relative growth measure (RCA), we find differing degrees of stability within the West German machine tool industry. The second part of the paper was devoted to the examination of reasons for changes in rank positions as well as growth activities from a short-term as well as a long-term perspective. The analysis reveals that there is no advantage for highly agglomerated regions with respect to growth and rank changes. There is even a negative effect as regions with a high number of firms develop worse than the industry. Moreover, we find that a general diversification strategy, i.e. becoming active in more product categories over time, has a positive effect on the development of regional growth. Lastly, we investigated in how far the adaptation to the changing demand conditions from conventional machine tools towards flexible multi-functional products (MFPs) influenced regional growth. Two results are brought forward. First, regions that get engaged in these new technologies generally have the highest number of firms in every point in time, and are also the most diversified ones. Secondly, further differentiation between early entrants, early followers and late entrants shows that there is evidence against the first mover advantage. Whereas late movers outperform non-entering regions in the fourth and fifth period (thus after their entry), early movers develop worse than regions entering later than the second period and as non-entering regions. Hence, this peculiar diversification strategy into new product or technological fields does not have a positive effect throughout all time periods, but only at a very specific point in time, i.e. from the 1980s onwards, when the market success for these types of products is achieved. Very early experience in this new technology field was thus not beneficial on the regional level as the technology itself underwent an evolutionary process. The implementation of the truly profitable features and advantages required a change in the entire product architecture and the development of new competencies, especially in the field of micro-electronics (Arnold, 1997).

The present paper focused on the regional level, but it clearly raises some interesting questions asking also for the integration of the firm level. Firstly, the combination of specific competencies in one region can only be realized via individual firms. Therefore, an investigation of the degree of diversification on the individual firm level might shed further light on the regions potential to combine certain competencies, as well as the general tendency of the actors to diversify or specialize already on a lower level. Secondly, it can be investigated whether a certain combination of skills in specific fields is more prone to foster entry into the analyzed newly emerging multi-functional products, respectively whether certain traditions are more successful than others despite the described competence-destroying effect. Moreover, studying the co-location of machine tool firms and electronic companies offers a prosperous setting to analyze the effects of regional proximity of complementary capabilities. Thirdly, the question whether old established firms or new entrants into the industry bring about change on the regional as well as industry level can be addressed in this context to further enrich the knowledge about renewal of industrial activities on a regional basis.

References

Agarwal, R., Echambadi, R., Franco, A.M. and Sarkar, M.B. (2004) Knowledge transfer through inheritance: spin-out generation, development and survival. *Academy of Management Journal* **47**: 501-522.

Albino, V., Garavelli, A.C. and Schiuma, G. (1999) Knowledge transfer and inter-firm relationships in industrial districts: the role of the leader firm, *Technovation* **19**, 53-63.

Arnold, H. (2003). *Technology shocks*. Physica-Verlag: Heidelberg.

Asheim, B. and Isaksen, A. (2002) Regional Innovation Systems: The Integration of Local 'sticky' and global 'ubiquitous' knowledge. *Journal of Technology Transfer* **27**, 77-86.

Bathelt, H., Malmberg, A. and Maskell, P. (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography* **28**, 31-56.

Boschma, R. and S. Iammarino (2007). Related variety and regional growth in Italy. Paper presented at the DRUID Summer Conference 2007 on Appropriability, proximity, routines and innovation. Copenhagen, june 18–20.

Brenner, T. (2004) *Local Industrial Clusters, Existence, Emergence and Evolution*, London: Routledge.

Brenner, T. and Fornahl, D. (2008) *Regional Path-Dependence in Start-up Activity*. Papers in Evolutionary Economics Geography #0812. Utrecht University, Section of Economics Geography.

Brenner, T. and Gildner, A. (2006)'The long-term Implications of Local Industrial Clusters',European Planning Studies,14:9,1315 — 1328

Carlsson, B. (1984). The development and use of machine tools in historical perspective. *Journal of Economic Behavior and Organization* 5: 91-114.

Carlsson, B. (1989). Small-scale industry at a crossroad: U.S. machine tools in global perspective. *Small Business Economics* 1: 245-261.

Cohen, W. M. and Levinthal, D. A. (1990) Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly* **35**, 128-152.

Deutsche Industriebank AG, 2004. *Märkte im Fokus: Maschinenbau in Deutschland Traditionsbranche mit hoher Innovationskraft.* IKB Report.

Ernst, H. (1997). The use of patent data for technological forecasting: the diffusion of CNC-technology in the machine tool industry. *Small Business Economics* 9: 361-381.

Feldman, M.P. and Audretsch, D.B. (1999) Innovation in cities: science-based diversity, specialization and localized competition. *European Economic Review* **43**, 409-429.

Fleischer, M. (1997). *The inefficiency trap: strategy failure in the German machine tool industry*. Berlin: Ed. Sigma.

Fornahl, D. (2007) *Changes in Regional Firm Founding Activities*, London: Routledge.

Frenken, K., van Oort, F.G. and Verburg, T. (2007) Related variety, unrelated variety and regional economic growth, *Regional Studies* **41**, 685-697.

Fritsch, M. and Mueller, P. (2005) The Persistence of Regional New Business Formation-Activity over Time – Assessing the Potential of Policy Promotion Programs, *Freiberg Working Papers #01-2005*.

Glaeser, E.L., Kallal, H.D., Schinkmann, J.A. and Shleifer, A. (1992) Growth in Cities. *Journal of Political Economy* **100**, 1126-1152.

Grabher, G. (1993) The Weakness of Strong Ties. The Lock-in of Regional Development in the Ruhr Area, in: G. Grabher (Ed) *The Embedded Firm*, London: Routledge, pp. 255-277.

Guenther, C. (2008). Towards automated manufacturing-creation, fusion and destruction of submarkets in the German machine tool industry, mimeo.

Hirsch-Kreinsen, H. (2000). The machine tool industry: new market challenges and the crisis of the traditional German pattern of innovation. In: Jürgens, K. (Ed.): New product development and production networks, Berlin/Heidelberg, pp.55-65.

Jacobs, J. (1969) *The economy of cities*, New York: Random House.

Klepper, S. (2006): The Evolution of Geographic Structure in New Industries, *Revue de L'OFCE* **97**, 135-158.

Klepper, S. and Sleeper, S. (2005) Entry by spinoffs. *Management Science* **51**: 1291-1306.

Marshall, A. (1890) *Principles of Economics*, London: Maxmillan.

Martin, R. and Sunley, P. (2006) Path dependence and regional economic evolution, *Journal of Economic Geography* **6**, 395-437.

Mazzoleni, R. (1997). Learning and path-dependence in the diffusion of innovations: comparative evidence on numerically controlled machine tools. *Research Policy* 26: 405-428.

Menzel, M.-P. and Fornahl, D. (2007) *Cluster Life Cycles – Dimensions and Rationales of Cluster Development*, Jena Economic Research Papers #2007-076, Jena.

Nooteboom, B. (2000) *Learning and Innovation in Organizations and Economies*. Oxford: Oxford University Press.

Oort, F. van (2002) Innovation and agglomeration economies in the Netherlands. *Journal of Economic and Social Geography* **93**, 344-360.

Paci, R. and Usai, S. (1999) Externalities, knowledge spillovers and the spatial distribution of innovation. *Geojournal* **49**, 381-390.

Panne, G. van der and Beers, C. van (2006) On the Marshall-Jacobs controversy: it takes two to tango. *Industrial and Corporate Change* **15**, 877-890.

Roy,R. and S. K. McEvily (2004). Incumbent survival during market fusion in maturing industries. In Baum, J. A. C. and A. M. McGahan (Eds.), Advances in Strategic Management, Vol. 21. Amsterdam: Elsevier Science.

Schwab, G. (1996). *Die Entwicklung der deutschen Werkzeugmaschinenindustrie von 1945-1995*. Master Thesis, University of Erlangen-Nürnberg, revised version edited by VDW, Frankfurt am Main

Shefer, D. and Frenkel, A. (1998) Local Milieu and Innovations. Some Empirical Results. *Annals of Regional Science* **32**, 185–200.

Sørensen, J.B. (1999) Executive migration and interorganizational competition. *Social Science Research* **28**, 289-315.

Sorenson, O. and Audia P.G. (2000) The social structure of entrepreneurial activity: geographic concentration of footwear production in the United States, 1940-1989. *American Journal of Sociology* **106**: 424-462.

Stuart, T.E. and Sorensen, O. (2003) The geography of opportunity: spatial heterogeneity in founding rates and the performance of biotechnology firms, *Research Policy* **32**, 229-253.

Tichy, G. (2001) Regionale Kompetenzzyklen - Zur Bedeutung von Produktlebenszyklus und Clusteransätzen im regionalen Kontext, *Zeitschrift für Wirtschaftsgeographie* **45**, 181-201.

VDMA (Verband Deutscher Maschinen- und Anlagenbau e.V.) (ed.) various years. *Wer baut Maschinen*. Frankfurt.

VDW (2005) Die deutsche Werkzeugmaschinenindustry im Jahr 2004. Verein Deutscher Werkzeugfabriken e.V. (Ed.): Frankfurt.

Weck, M. and C. Brecher (2005). *Werkzeugmaschinen: Maschinenarten und Anwendungsbereiche*. Springer: Berlin.

WS Atkins Management Consultants (1990). *Strategic study on the EC machine tool sector.* Brussels: Commission of the European Communities.

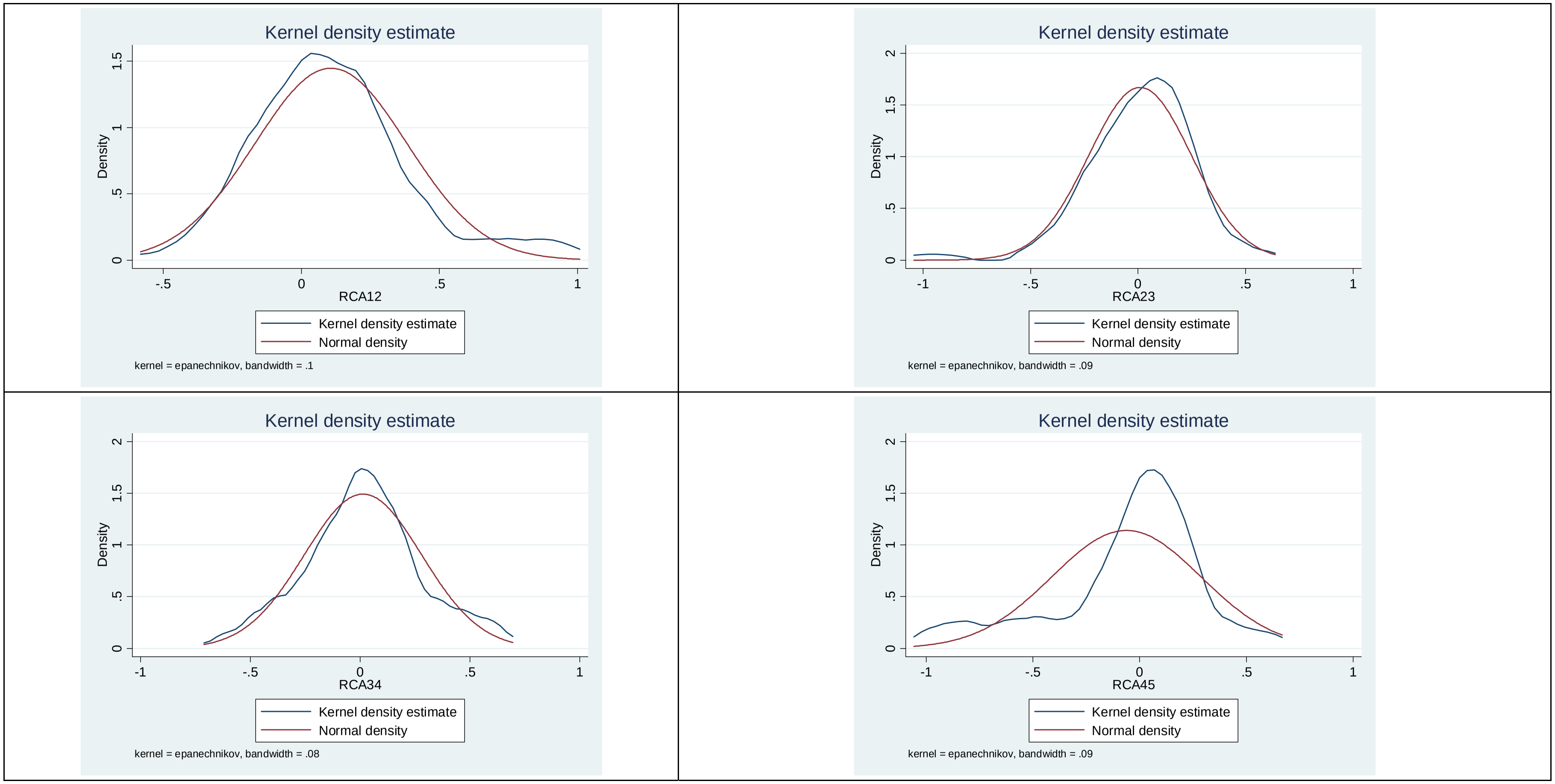

Figure A.1: Kernel density estimates for RCA

Table A.1: Summary statistics of variables

Variable	Observations	Mean	Std. Dev.	Min	Max
rca12	64	0.107	0.276	-0.487	0.912
rca23	64	0.009	0.239	-0.953	0.548
rca34	64	0.013	0.267	-0.632	0.615
rca45	63	-0.063	0.350	-0.966	0.576
rca15	63	0.045	0.516	-0.976	0.911
rca14	64	0.117	0.392	-0.831	0.950
rca25	63	-0.037	0.467	-0.989	0.831
rc12	63	0.048	5.081	-11	19
rc23	63	-0.063	4.254	-11	13
rc34	63	-0.048	5.056	-14	15
rc45	63	-0.190	7.080	-30	15
rc15	63	-0.254	10.563	-26	25
rc14	63	-0.063	8.466	-24	19
rc25	63	-0.302	9.131	-22	25
firmen5362	64	11.836	21.659	0.3	150.6
firmen6372	64	11.847	18.970	1	129.5
firmen7382	64	10.370	15.410	0.3	99.2
firmen8392	64	9.488	13.598	0.5	83.2
firmen932002	64	7.202	10.524	0	60.2
hhiper1	64	0.263	0.179	0.073	1
hhiper2	64	0.261	0.197	0.076	1
hhiper3	64	0.281	0.218	0.077	1
hhiper4	64	0.308	0.276	0.075	1
hhiper5	63	0.334	0.285	0.077	1
chhi12	64	-0.002	0.115	-0.628	0.389
chhi23	64	0.020	0.123	-0.423	0.523
chhi34	64	0.027	0.169	-0.447	0.513
chhi45	63	0.037	0.147	-0.449	0.576
chhi14	64	0.045	0.203	-0.279	0.770
chhi25	63	0.074	0.238	-0.358	0.785
chhi15	63	0.083	0.235	-0.189	0.816
cprdcount12	64	1.247	1.454	-2.5	4.6
cprdcount23	64	0.072	1.959	-4.1	6.2
cprdcount34	64	0.158	2.056	-4.8	6.8
cprdcount45	64	-2.133	2.480	-11.3	2.3
cprdcount14	64	1.477	3.267	-9.1	9.7
cprdcount25	64	-1.903	3.565	-15.6	3.6
cprdcount15	64	-0.656	3.552	-14.7	5.9
entry1	64	0.000	0.000	0	0
entry2	64	0.281	0.453	0	1
entry3	64	0.203	0.406	0	1
entry4	64	0.172	0.380	0	1
entry5	64	0.063	0.244	0	1

Table A.2: Robust OLS linear regressions

	Number of firms in start period	HHI in start period	Change of HHI	Change in number of product categories	Region active in MP in start or end period	Cons	r-square	Observations
RCA12	-0.0031***	0.1447	-0.5572	0.0536***	-0.0294	0.047	0.2461	64
	(-2.77)	(-0.5)	(-1.47)	(-3.1)	(-0.55)	(-0.52)		
RCA23	-0.0018**	-0.1469	-0.5584	0.0434***	-0.0108	0.0818	0.2797	64
	(-2.43)	(-0.56)	(-1.13)	(-4.43)	(-0.14)	(-0.84)		
RCA34	-0.0009	0.1684	-0.3914*	0.0434***	-0.0013	-0.02	0.2794	64
	(-0.72)	(0.89)	(-1.68)	(3.24)	(-0.02)	(-0.18)		
RCA45	-0.0033**	-0.1486	-0.5674*	0.0778***	0.3437***	-0.0376	0.5268	63
	(-2.4)	(-0.65)	(-1.71)	(4.73)	(3.75)	(-0.29)		
RCA14	-0.0058**	-0.0972	-0.2037	0.0576***	-0.0788	0.1868	0.3429	64
	(-5.16)	(-0.42)	(-0.84)	(5.33)	(-0.65)	(1.28)		
RCA25	-0.0046***	0.2104	-0.2533	0.0653***	0.4594***	-0.2299	0.5093	63
	(-2.88)	(0.66)	(-0.99)	(5.02)	(3)	(-1.12)		
RCA15	-0.0082***	-0.3673	-0.3474	0.0791***	0.1831	0.1824	0.456	63
	(-6.65)	(-0.89)	(-1.03)	(5.42)	(0.88)	(0.69)		
RC12	-0.017	5.4745	-14.529	0.8382**	0.7234	-2.2524	0.148	63
	(-1.15)	(1.04)	(-1.36)	(2.26)	(0.58)	(-1.25)		
RC23	0.0009	3.1077	-7.5423	0.8477***	0.2178	-0.9321	0.2912	63
	(0.08)	(0.91)	(-1.33)	(3.4)	(0.16)	(-0.59)		
RC34	-0.008	0.8926	-1.267	0.858***	0.0272	-0.3502	0.1428	63
	(-0.38)	(0.24)	(-0.31)	(3.72)	(0.01)	(-0.15)		
RC45	-0.0828***	2.4642	-1.4085	1.7274***	7.3752***	-1.4972	0.4701	63
	(-2.98)	(0.66)	(-0.27)	(3.66)	(2.81)	(-0.49)		
RC14	-0.0157	9.9722	0.3153	1.091***	0.0727	-4.0825	0.1976	63
	(-0.82)	(1.08)	(0.07)	(3.73)	(0.02)	(-0.93)		
RC25	-0.0571**	8.2257	2.1882	1.5082***	7.5919***	-4.5937	0.4543	63
	(-2.2)	(1.62)	(0.49)	(5.62)	(2.66)	(-1.29)		
RC15	-0.0801***	4.1792	1.1273	1.6679***	4.3498	-2.5202	0.3543	63
	(-2.69)	(0.44)	(0.21)	(5.29)	(1.07)	(-0.47)		

Note: Coefficients and t-values reported in cells; ***p<=0.01; **p<=0.05; *p<=0.1; shaded cells are at least significant with p<=0.1

Table A.3: Robust OLS linear regressions with timing of entry

	Number of firms in start period	HHI in start period	Change of HHI	Change in number of product categories	Entry in MP category in time period… 2	3	4	5	Cons	r-square	Observations
RCA12	-0.0031***	0.1447	-0.5572	0.0536***	-0.0294				0.047	0.2461	64
	(-2.77)	(-0.5)	(-1.47)	(-3.1)	(-0.55)				(-0.52)		
RCA23	-0.0015**	-0.1479	-0.5586	0.0425***	-0.0295	0.0077			0.0802	0.2821	64
	(-2.31)	(-0.55)	(-1.12)	(4.18)	(-0.4)	(0.09			(0.82)		
RCA34	-0.0015	0.1648	-0.3764	0.0457***	0.0312	-0.0277	0.0042		-0.0183	0.2841	64
	(-1.16)	(0.75)	(-1.59)	(3.3)	(0.3)	(-0.27)	(0.04)		(-0.15)		
RCA45	-0.0031**	-0.112	-0.5293	0.0821***	0.3717***	0.4291***	0.3564***	0.3164**	-0.0803	0.5391	63
	(-2.23)	(-0.46)	(-1.53)	(4.86)	(3.21)	(3.79)	(3.38)	(2.44)	(-0.56)		
RCA14	-0.006***	-0.1259	-0.2215	0.0629***	-0.0834	-0.1952	0.0113		0.1993	0.3671	64
	(-5.7)	(-0.49)	(-0.93)	(5.63)	(-0.62)	(-1.42)	(0.07)		(1.28)		
RCA25	-0.0047**	0.1892	-0.2645	0.0659***	0.4609**	0.4278**	0.4818***	0.4385**	-0.2168	0.5106	63
	(-2.63)	(0.52)	(-0.95)	(4.74)	(2.36)	(2.34)	(2.67)	(2.65)	(-0.97)		
RCA15	-0.0083***	-0.4388	-0.4023	0.0798***	0.1547	0.0825	0.2623	0.1243	0.2255	0.4674	63
	(-6.57)	(-0.92)	(-1.14)	(5.2)	(0.61)	(0.35)	(1.14)	(0.54)	(0.76)		
RC12	-0.017	5.4745	-14.529	0.8382**	0.7234				-2.2524	0.148	63
	(-1.15)	(1.04)	(-1.36)	(2.26)	(0.58)				(-1.25)		
RC23	0.0038	3.0971	-7.5452	0.8384***	0.0295	0.4036			-0.9475	0.292	63
	(0.25)	(0.89)	(-1.32)	(3.34)	(0.02)	(0.25)			(-0.59)		
RC34	-0.0107	0.2426	-1.0624	0.8795***	-0.0425	-0.6898	0.5257		-0.0693	0.1479	63
	(-0.5)	(0.06)	(-0.26)	(3.82)	(-0.02)	(-0.29)	(0.23)		(-0.03)		
RC45	-0.0438	2.7574	-1.2152	1.6709***	5.8719	8.3049**	7.7792***	7.9571**	-2.1928	0.4784	63
	(-1.34)	(0.64)	(-0.19)	(3.26)	(1.43)	(2.15)	(2.71)	(2.32)	(-0.6)		
RC14	-0.0296	10.3094	0.2876	1.1975***	1.0823	-2.135	1.2306		-4.1942	0.2165	63
	(-1.63)	(1.1)	(0.06)	(3.88)	(0.31)	(-0.57)	(0.29)		(-0.92)		
RC25	-0.0388	6.6839	1.3544	1.4487***	5.6844	6.7504*	8.2037**	8.4258***	-3.906	0.4617	63
	(-1.26)	(1.13)	(0.28)	(5.25)	(1.56)	(1.94)	(2.15)	(2.91)	(-0.99)		
RC15	-0.0737**	1.4219	-0.7056	1.6519***	2.5865	1.5687	6.5591	3.4818	-1.0163	0.376	63
	(-2.51)	(0.14)	(-0.12)	(4.96)	(0.54)	(0.33)	(1.29)	(0.84)	(-0.18)		

Note: Coefficients and t-values reported in cells; ***p<=0.01; **p<=0.05; *p<=0.1; shaded cells are at least significant with p<=0.1